SUPPLEMENT

TO BRITISH TELECOMMUNICATIONS ENGINEERING

(formerly the Supplement to The Post Office Electrical Engineers' Journal)

Vol. 5 Part 4 January 1987

ISSN 0262-4028

BTEC & CGLI
GUIDANCE FOR STUDENTS

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CITY AND GUILDS OF LONDON INSTITUTE

Telecommunications Technicians (New) Scheme

The following questions are from examination papers set for the City and Guilds of London Institute's (CGLI's) new 271 Telecommunications Technicians Scheme, and are reproduced with the permission of the CGLI. The answers given have been prepared by independent authors. Answers to some questions are occasionally omitted because of insufficient space. Students studying BTEC courses may find that these questions are useful for revision.

CGLI: ELECTRONICS T4 (1985)

Students are advised to read the notes above. The time for the paper was three hours. Students had to answer six questions

Q1 For the Colpitts oscillator shown in Fig. 1

(a) derive an expression for the maintenance conditions of the circuit

(b) obtain an expression for the minimum value of h_{fe} required by TR1 to maintain oscillation.

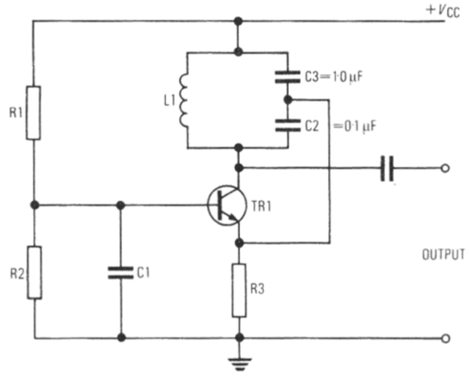


Fig. 1

A1 (*a*) [*Tutorial Note:* The method used to solve this question is the j-operator method.]

Let $jX_1 = j\omega L_1$ (this represents the reactance of inductor L1),

$jX_2 = \frac{1}{j\omega C_2}$ (this represents the reactance of capacitor C2), and

$jX_3 = \frac{1}{j\omega C_3}$ (this represents the reactance of capacitor C3).

$\omega = 2\pi f$, where f is frequency.
At the frequency of oscillation, f_0,

$$X_1 + X_2 + X_3 = 0.$$

$$\therefore \quad j\omega_0 L_1 + \frac{1}{j\omega_0 C_2} + \frac{1}{j\omega_0 C_3} = 0.$$

Multiplying through by j gives

$$j^2\omega_0 L_1 + \frac{1}{\omega_0 C_2} + \frac{1}{\omega_0 C_3} = 0.$$

$$\therefore \quad \frac{1}{\omega_0 C_2} + \frac{1}{\omega_0 C_3} - \omega_0 L_1 = 0.$$

$$\therefore \quad \frac{1}{\omega_0 C_2} + \frac{1}{\omega_0 C_3} = \omega_0 L_1.$$

$$\therefore \quad \frac{1}{C_2} + \frac{1}{C_3} = \omega_0^2 L_1.$$

$$\therefore \quad \omega_0^2 = \frac{1}{L_1}\frac{(C_2 + C_3)}{(C_2 C_3)}.$$

$$\therefore \quad \underline{f_0 = \frac{1}{2\pi\sqrt{\left\{\frac{L_1 C_2 C_3}{(C_2 + C_3)}\right\}}}}.$$

(*b*) It can be shown from the three-impedance representation of the Colpitt's oscillator that, at the frequency of resonance,

$$X_3(1 + h_{fe}) + X_1 = 0.$$

$$\therefore \quad X_3(1 + h_{fe}) = -X_1.$$

$$\therefore \quad \frac{-X_1}{X_3} = (1 + h_{fe}).$$

$$\therefore \quad h_{fe,min} = -1 - \frac{X_1}{X_3},$$

$$= -1 - \frac{j\omega_0 L_1}{\frac{1}{j\omega_0 C_3}},$$

$$= -1 + \omega_0^2 L_1 C_3,$$

$$= -1 + \left(\frac{C_2 + C_3}{C_2 C_3}\right)\frac{L_1 C_3}{L_1},$$

$$= -1 + 1 + \frac{C_3}{C_2},$$

$$= \underline{\frac{C_3}{C_2}}.$$

Q2 (a) Draw a circuit diagram of a field-effect transistor (FET) connected as a class A single stage amplifier in

(i) common-drain configuration
(ii) common-gate configuration.

(b) Compare the circuits in (a) in terms of

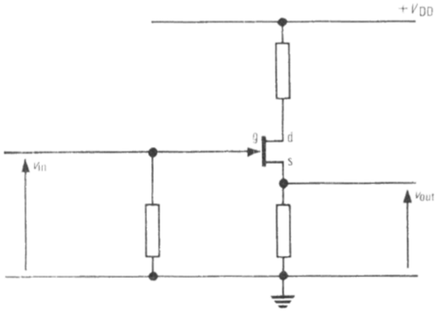
(i) input impedance
(ii) output impedance

(iii) voltage gain.

(c) Sketch the equivalent circuit of a common source connected FET

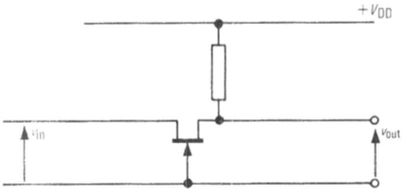
(i) at high frequency
(ii) at low frequency.

A2 *(a)*



g = gate   d = drain   s = source

(i) Common drain

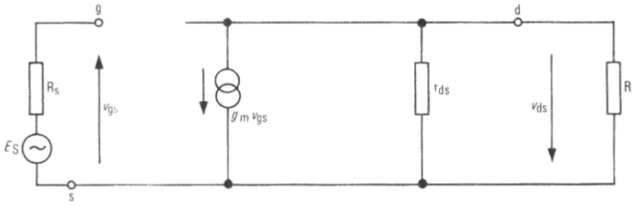


(ii) Common gate

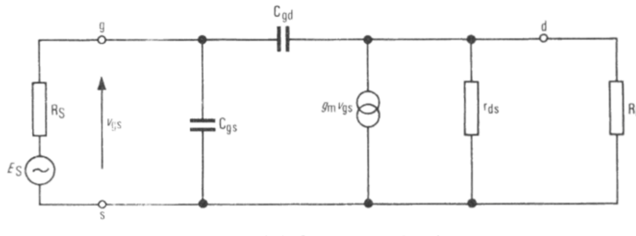
(b) [*Tutorial Note:* The best way to answer questions of this type (that is, to make comparisons) is to use a table.]

	Common Drain	Common Gate
Input Impedance	Very high	Low
Output Impedance	Very low	High
Voltage Gain	<1	High

(c)



(i) Low-frequency circuit



(ii) High-frequency circuit

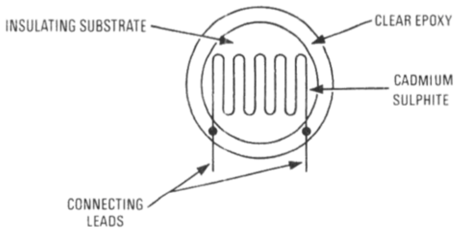
Q3 *(a) Describe, with the aid of a sketch, the construction and operation of a photo-conductive cell.*

(b) State the main advantage of a photo-diode compared to a photo-conductive cell.

(c) With the aid of a circuit diagram, describe ONE *application of a photo-conductive cell.*

A3 *(a)* The principle of operation of a photo-conductive cell is that its conductivity varies with the level of light reaching it; that is, the resistance of the cell is high in dark conditions (for example, 10 MΩ), and low in bright conditions (for example, 10 Ω).

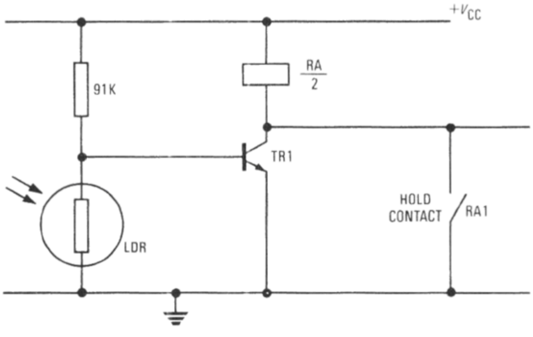
The cell is also known as a *light-dependent resistor* (LDR). Its construction is shown in sketch *(a)*. A sensitive layer of cadmium sulphite is deposited onto an insulating substrate. The assembly, with connecting leads, is then enclosed in clear epoxy resin.



(a)

(b) A photo-diode has a much faster response time, 250 ns, as compared with 5 or 6 ms for an LDR.

(c) An example of an application for a photo-conductive cell is a porch light which switches on when the ambient-light level falls with approaching darkness (see sketch *(b)*).



(b)

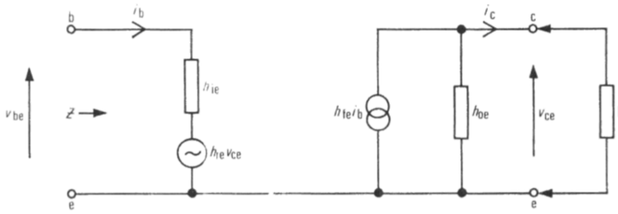
When light impinges on the LDR, the resistance of the LDR is low. Transistor TR1, therefore, is OFF, contact RL1 is OFF and the porch light is switched OFF.

When the light level falls, the resistance of the LDR is high. Transistor TR1 receives current via the 91 kΩ resistor and is switched ON, contact RL1 is switched ON (hold contact) and the porch light is switched ON.

Q4 *A bipolar transistor is connected as a common-emitter amplifier*

(a) draw its h parameter equivalent circuit
(b) derive its current gain A_i
(c) derive its input resistance R_{in}.

A4 *(a)*



(b)

$$v_{be} = h_{ie}i_b + h_{re}v_{ce}. \qquad \ldots\ldots(1)$$

$$i_c = h_{fe}i_b + h_{oe}v_{ce}. \qquad \ldots\ldots(2)$$

$$A_i = \frac{i_c}{i_b}. \qquad \ldots\ldots(3)$$

$$v_{ce} = -i_c R_L. \qquad \ldots\ldots(4)$$

Therefore, from equations (2) and (4),

$$i_c = h_{fe} i_b + h_{oe}(-i_c R_L).$$

$$\therefore \quad i_c + i_c R_L h_{oe} = h_{fe} i_b.$$

$$\therefore \quad i_c(1 + R_L h_{oe}) = h_{fe} i_b. \qquad \ldots\ldots(5)$$

Therefore, from equations (3) and (5),

$$A_i = \frac{i_c}{i_b} = \underline{\frac{h_{fe}}{1 + R_L h_{oe}}}.$$

(*c*)

$$R_{in} = Z = \frac{v_{be}}{i_b}.$$

But, from equations (1) and (4),

$$v_{be} = h_{ie} i_b + h_{re} v_{ce},$$

$$= h_{ie} i_b - h_{re} i_c R_L.$$

But, from the expression for A_i derived in part (*b*),

$$i_c = \frac{i_b h_{fe}}{1 + R_L h_{oe}}.$$

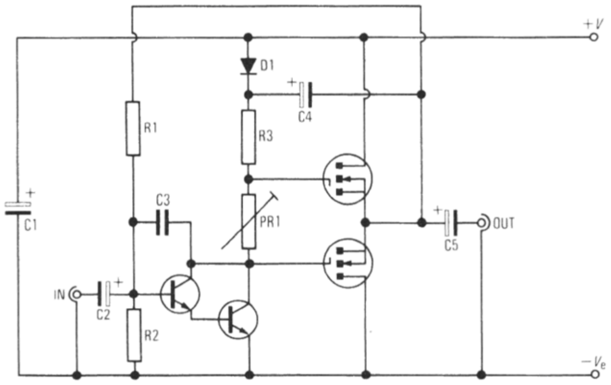
$$\therefore \quad v_{be} = h_{ie} i_b - \frac{h_{re} i_b h_{fe} R_L}{1 + R_L h_{oe}}.$$

$$\therefore \quad R_{in} = \frac{v_{be}}{i_b} = \underline{h_{ie} - \frac{h_{re} h_{fe} R_L}{1 + R_L h_{oe}}}.$$

Q5 *(a) Explain, with the aid of a circuit diagram, the operation of a Class B push-pull power amplifier using V-MOS devices in the output stage.*

(b) Describe how cross-over distortion which may occur in the circuit in (a) can be minimised.

A5 (*a*) See sketch.



[*Tutorial Note:* The operation of the circuit is similar to that using bipolar transistors.]

Complementary V-MOS output transistors are used as source followers driven by a Darlington pair. The Darlington pair is biased by resistors R1 and R2. The positive signal swing is passed by one V-MOS device, while the other V-MOS device is cut OFF. The negative-going swing switches OFF the device that was previously ON and vice versa. The two half cycles are combined in the load in the usual manner.

(*b*) Cross-over distortion is caused by the non-linear input characteristics of bipolar transistors, and does not occur with V-MOS devices. With bipolar transistors, it is essential to slightly forward bias the output transistors; that is operate in Class AB.

Q6 *(a) Describe FOUR important characteristics of an opto-coupler.*

(b) Sketch a labelled circuit diagram of an interface between an opto-coupler and a logic control system.

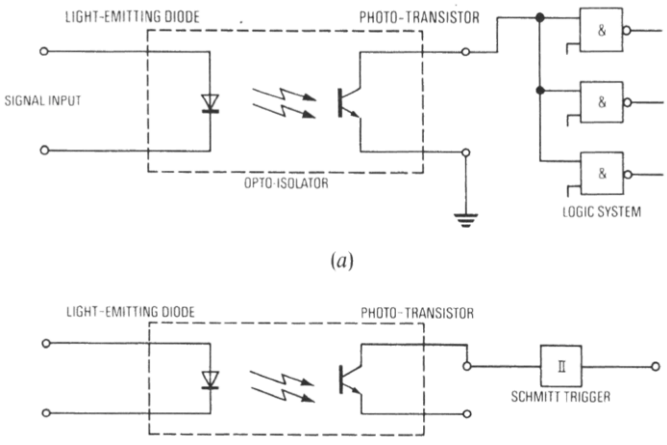
A6 (*a*) (*i*) The transfer characteristic or gain ratio of the output current to the input current; that is, the current transfer ratio (CTR).

(*ii*) The frequency response. This should not be confused with the spectral response of the system. The frequency response is a measure of how quickly the system can respond to changes in input signal.

(*iii*) Isolation; that is, electrical insulation, ground-loop prevention, electrical-noise isolation, common-mode rejection.

(*iv*) Noise immunity; that is, the ability to resist interference from internal and external sources of noise.

(*b*) Alternative systems are shown in sketches (*a*) and (*b*).



(*a*)

(*b*)

Q7 *(a) List and define the y parameters of a small signal amplifier.*

(b) A transistor has the following y parameters, $y_{ie} = 500\ \mu S$, $y_{fe} = 0{\cdot}03\ \mu S$, $y_{oe} = 40\ \mu S$ *and* y_{re} *is negligible. If the transistor is connected in the circuit shown in Fig. 2 (below) calculate*

(i) the signal current through R_L

(ii) the signal voltage developed across R_L

(iii) the voltage gain.

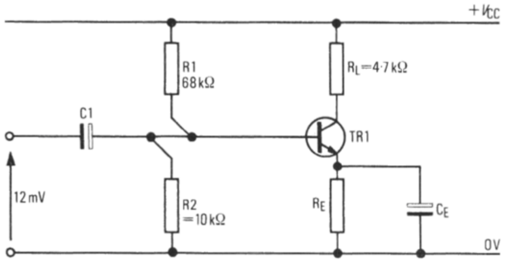


Fig. 2

A7 The *y* parameters are defined as follows:

(*i*) $y_i = \dfrac{i_1}{v_1};\ v_2 = 0.$

This is the input admittance, and is the ratio of the small change in input current to the corresponding change in input voltage with the output voltage held constant at zero.

(*ii*) $y_r = \dfrac{i_1}{v_2};\ v_1 = 0.$

This is the reverse transfer admittance, and is the ratio of the small change in input current to the corresponding change in output voltage with the input voltage held constant at zero.

(*iii*) $y_f = \dfrac{i_2}{v_1};\ v_2 = 0.$

This is the forward transfer admittance, and is the ratio of a small change in output current to a corresponding change in input voltage with the output voltage held constant at zero.

(*iv*) $y_o = \dfrac{i_2}{v_2};\ v_1 = 0.$

This is the short circuit output admittance and is a ratio of the small change in output current to a corresponding change in output voltage, with input voltage held constant at zero.

(*b*) The voltage gain, A_v, is given by

$$-\frac{y_{fe}}{y_L + y_{oe}} = -\frac{0{\cdot}03}{\dfrac{1}{4{\cdot}7 \times 10^3} + \dfrac{40}{10^6}},$$

$$= \underline{-118{\cdot}7.}$$

The signal voltage, v_0, across resistor R_L is given by

$$v_0 = v_{in} A_v = 12 \times 10^{-3} \times 118{\cdot}7 = \underline{1{\cdot}424\ \text{V}.}$$

The signal current through resistor R_L is given by

$$\frac{v_0}{R_L} = \frac{1{\cdot}424}{4{\cdot}7 \times 10^3} = 0{\cdot}303\ \text{mA}.$$

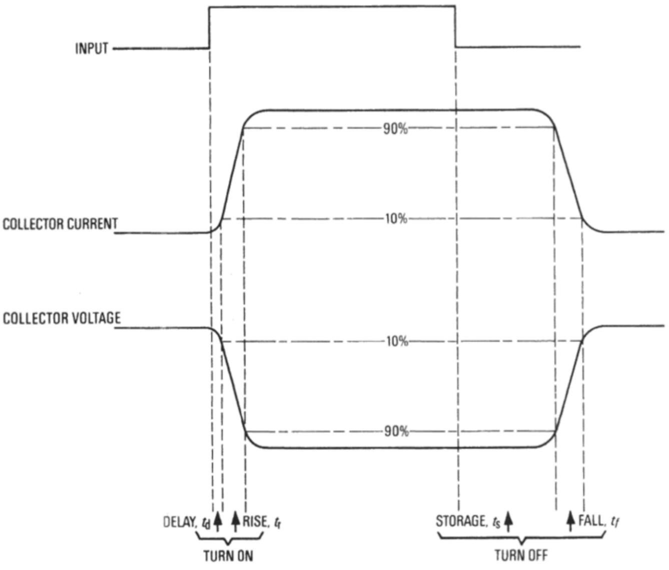
Q8 *(a) Sketch the collector current waveform for a common-emitter transistor switch when a rectangular voltage pulse is applied to its base. Identify on the sketch*

(i) delay time
(ii) rise time
(iii) storage time.

(b) With respect to (a)(i)(ii)(iii), describe THREE *methods of improving the switching times of transistors.*

(c) Sketch the output characteristics of a transistor connected as in (a) and indicate clearly the areas of application for switching.

A8 (*a*) See sketch (*a*).



(*a*)

Typical figures for a BFW 90 transistor at 200 MHz are

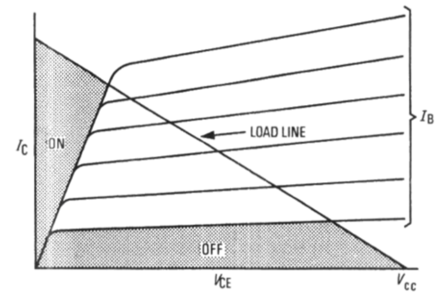
$$t_d = 5\ \text{ns},\quad t_r = 18\ \text{ns},\quad t_s = 95\ \text{ns},\quad t_f = 30\ \text{ns}.$$

(*b*) (*i*) A speed-up capacitor provides an easy discharge path for stored base current carriers when the input drive goes negative.

(*ii*) The use of a Schockley diode ensures that it is impossible to forward bias the base–collector junction. Therefore, there is always a barrier field across the base–collector junction. Electrons are kept clear of the base, which is kept unsaturated.

(*iii*) The turn ON time is reduced by using a large base drive but this causes problems with switching OFF.

(*c*)



Q9 *(a) Explain the operation of the stabilised DC power supply circuit shown in Fig. 3 (below) when*

(i) the resistance of the load increases
(ii) the mains voltage falls.

(b) Describe the operation of the part of the circuit containing TR4.

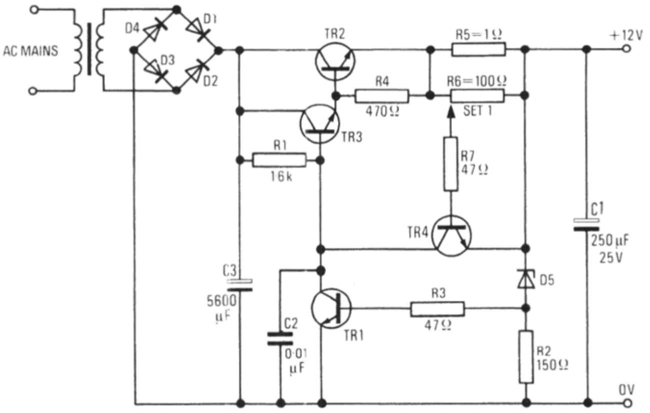


Fig. 3

A9 (*a*) (*i*) If the resistance of the load increases, the following sequence of events follows:

1 The load current decreases.
2 The output voltage rises.
3 The voltage at the top of resistor R2 rises.
4 The voltage on base of transistor TR1 rises.
5 The collector voltage of transistor TR1 falls since TR1 is connected in the common-emitter configuration.
6 The base voltage of transistor TR3 falls.
7 The emitter voltage of transistor TR3 falls.
8 The base voltage of transistor TR2 falls.
9 The output voltage falls.

Therefore, the original rise in the output voltage is compensated for.

(*ii*) If the mains voltage falls, the following sequence of events follows:

1 The output voltage of the rectifier falls.
2 The base voltage of transistor TR3 falls.
3 The emitter voltage of transistor TR3 falls.
4 The base voltage of transistor TR2 falls.
5 The emitter voltage of transistor TR2 falls.

Therefore, the base voltage of transistor TR1 falls and the collector voltage of transistor TR3 rises. This voltage is fed to the base of transistor TR3 and corrective action as described above follows.

(*b*) The part of the circuit containing transistor TR4 is a current limit. Excess current flow causes extra voltage to be developed across resistor R5 and therefore R6. Transistor TR4 is driven further into conduction and the collector voltage of transistor TR4 falls, driving transistors TR3 and TR2 OFF. Thus the output voltage falls and the output current is limited.

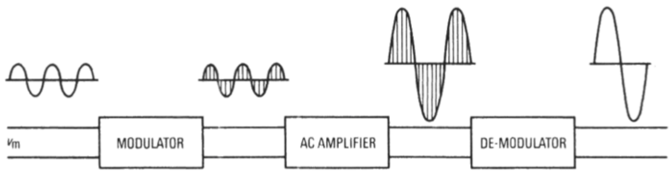
Q10 *(a) Describe with the aid of a schematic diagram the principle of operation of a chopper stabilised amplifier.*

(b) Give TWO *reasons why the chopper stabilised amplifier is preferred in some applications to a high gain DC amplifier.*

(c) State ONE *application of the chopper stabilised amplifier.*

A10 (*a*) Assume that a very small signal is to be amplified (v_m) and it is of a very low frequency. Its period is either minutes or even hours. AC amplifiers are not a practical solution as the coupling capacitors would cause too much signal loss at the low frequencies involved. DC amplification is therefore required, with its inherent drift problems.

A solution to the problem is to use a chopper amplifier as shown in the sketch. The principle of operation is to modulate the slowly changing input (chopped) and then use an AC amplifier to amplify the modulated signal. The amplified signal is then demodulated to reconstitute an amplified version of the original signal.



(*b*) DC amplifiers are subject to drift because of temperature changes or any offset voltages, and this is amplified along with the required signal and appears at the output.

(*c*) Instrumentation, solar detectors.

Answers contributed by E. J. Morris

CGLI: SWITCHING T4 OPTION (1986)

Students are advised to read the notes on p. 69. Students were required to answer any six questions. The time allowed was three hours

Q1 *(a) An average busy hour traffic of one erlang is offered to a full availability group of three trunks. If the average holding time of the calls is three minutes apply the erlang lost call formula to calculate*

(i) the grade of service
(ii) the traffic lost
(iii) the number of calls offered to, carried by and lost from the group.

(b) Explain why a large group of trunks is more efficient than a small group of trunks for the same grade of service.

A1 (*a*) (*i*) If N is the number of circuits and A the traffic offered, then the grade of service, B, is given by

$$B = \frac{\dfrac{A^N}{N!}}{1 + A + \dfrac{A^2}{2!} + \dfrac{A^3}{3!} + \cdots + \dfrac{A^N}{N!}}.$$

But, $N = 3$ and $A = 1$.

$$\therefore \quad B = \frac{\dfrac{1^3}{3!}}{1 + 1 + \dfrac{1^2}{2!} + \dfrac{1^3}{3!}},$$

$$= \frac{\dfrac{1}{6}}{1 + 1 + \dfrac{1}{2} + \dfrac{1}{6}},$$

$$= \underline{0{\cdot}0625}.$$

(*ii*) The traffic lost

$$= \text{traffic offered} \times \text{grade of service},$$

$$= 1 \times 0{\cdot}0625,$$

$$= \underline{0{\cdot}0625 \text{ erlangs}}.$$

(*iii*) The traffic in erlangs

$$= \text{number of calls} \times \text{average holding time } (C) \text{ (in hours)}.$$

For an offered traffic of 1 erlang, and an average holding time for calls of three minutes,

$$1 = C \times \frac{3}{60}.$$

$$\therefore \quad C = 20.$$

Therefore, the number of calls offered is $\underline{20}$.
The number of calls lost

$$= \text{the number of calls offered} \times \text{grade of service},$$

$$= 20 \times 0{\cdot}0625,$$

$$= \underline{1{\cdot}25}.$$

The number of calls carried

$$= \text{number of calls offered} - \text{number of calls lost},$$

$$= 20 - 1{\cdot}25,$$

$$= \underline{18{\cdot}75}.$$

(*b*) See A1, Part (*a*) (*i*), Switching T4 Option (1985), *Supplement*, Vol. 4, p. 45, Jan. 1986.

Q2 *For the control area of a large reed-relay electronic exchange (TXE4 or equivalent)*

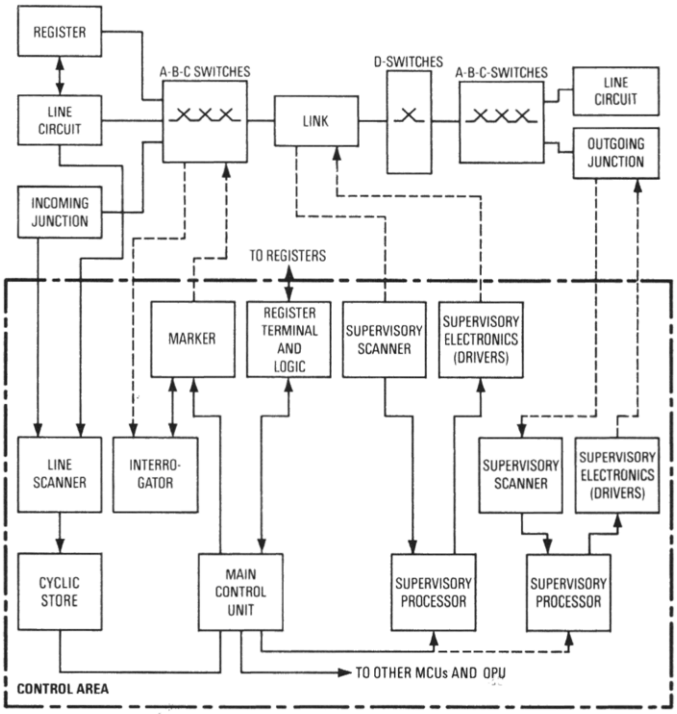
(a) list five items of equipment
(b) draw a block diagram which clearly indicates how the items in (a) are interconnected
(c) describe in general terms the functions of the equipment when setting up connections through the switching network
(d) give one example where security is taken into account.

A2 (*a*) The following items of equipment make up the control area of a TXE4A exchange:

(*a*) markers,
(*b*) interrogators,
(*c*) supervisory processing units,
(*d*) main control units,
(*e*) registers,
(*f*) scanners,
(*g*) the cyclic store,
(*h*) operations processing unit, and
(*i*) supervisory electronics.

[*Tutorial Note:* Only five items of equipment are asked for.]

(*b*) A block diagram of the control equipment is given in the sketch.



[*Tutorial Note:* More detail is given in the diagram to show fully the relationship between the switching equipment and the control area.]

(*c*) The control area is based on the main control unit (MCU), the operations processing unit (OPU) and the cyclic store. The MCU controls the sequence of a call by a series of steps. Up to 19 MCUs plus one OPU can be used in an exchange, depending on the size of the exchange. The OPU monitors and updates cyclic store data, controls exchange routing, controls the non-volatile record of cyclic store data (which is used for backup) and provides man–machine interface (MMI).

The cyclic store is a library of information on all peripheral circuits and provides translations, the information being cyclically generated. Peripheral circuits are connected to scan gates which are cyclically scanned at the same time as their cyclic store information is generated, to determine their state of line (for example, FREE, BUSY, CALLING); action is taken when necessary to connect a calling line. The MCU, using information from the cyclic store, controls the markers and interrogators, which inspect the switching network and pass 'path available' information back to the MCU to select the pair of adjacent planes to be used. The appropriate markers then set up the selected path. At various times during the setting up of a call, paths are checked to ensure that they are correctly established. Once the path has been set up, the control equipment is released and the supervisory processing unit (SPU), which has received instructions relating to the call from the MCU, takes control of the call. The SPU supervises metering, local call timing and cleardown and interfaces with the supervisory circuits via the supervisory electronics.

(*d*) One example where security is taken into account is the SPUs. All supervised circuits (links and outgoing junctions) are supervised by three SPUs working in synchronism for security reasons. If one of the three SPUs fails for some reason, the circuit is unaffected as its supervision continues under the control of the remaining SPUs.

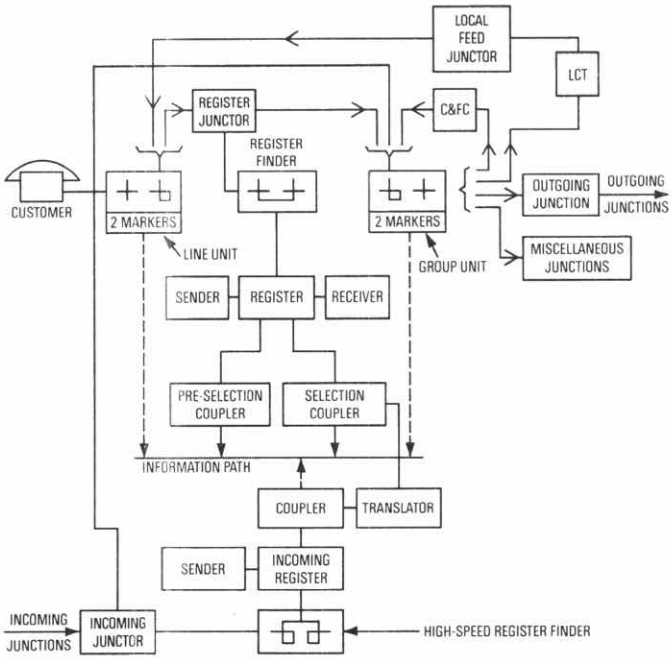
Q3 *For a Pentaconta type crossbar exchange*

(a) sketch and label a block diagram that includes both the switching network and the control area

(b) describe the sequence of events that occurs when connecting the switching network and the control area together via an information path

(c) explain how the holding time of the information path is kept to a minimum by the method adopted to transmit information.

A3 (*a*) A block diagram of the TXK3 or Pentaconta-type crossbar exchange is given in the sketch.



(*b*) The sequence of events that occurs when the switching network and the control area are connected together via an information path is related to the type of call being set up.

For a call set up between two subscribers on the same exchange, the sequence of events can be divided into four stages as follows:

(*i*) *Preselection* The calling customer's line unit sends a *start* signal to a register finder, which seizes a free register and connects it via a register junctor to a free inlet of the line unit. The line unit marker is engaged to prepare a path, through the multiswitches, connecting the seized inlet to the calling customer's outlet. When the preparation is complete, the marker uses the information path to inform the register of the type of line that is about to be connected. After storing this information, the register causes the prepared path to be switched and connects dial tone to the caller.

(*ii*) *Dialling* The calling customer dials the number of the called customer, the digits being stored in the register. Before switching commences, the register uses the translator to convert some of the dialled digits into routing digits that specify the outlets of the group unit to be marked. In exchanges with two stages of group selection, two types of translator are provided. The originating translator supplies routing digits for the first-stage group unit and the local translator supplies routing digits for the second-stage group unit. The selection coupler gives the register access to both translators.

(*iii*) *Group Selection* When the routing digits from the translator are stored in the coupler, the group unit inlet is seized and connected to a marker. The information path is used to pass the routing digits to the marker, which marks all free outlets in the required route. A path is prepared, through the multiswitches, from the seized inlet to a marked outlet. When the preparation is complete, the marker uses the information path to inform the register of the type of outlet to which it is being connected. After storing this information, the register causes the prepared path to be switched. The call has now been connected, through a local feed junctor which will provide a transmission bridge when switching is completed, to an inlet of the next switching unit.

(*iv*) *Line Selection* When dialling is complete, the register seizes a line unit inlet over the path already switched through the group unit. The line unit inlet seizes a marker. The last three dialled digits are sent from the register to the marker by using the selection coupler and information path. The line unit outlet which serves the called customer's line is marked if it is free. A path is prepared, through the multiswitches, from the seized inlet to the marked outlet. The marker uses the information path to inform the register of the type of line that is going to receive the call. The register then causes the prepared path to be switched and sends a signal to the local feed junctor for the transmission bridge to be connected into the circuit.

During the setting up of the call, the register has been holding the switched path. The local feed junctor now takes over the holding of the call, and the register and register finder are released.

[*Tutorial Note:* The sequence of events has been described in more detail than would be expected in examination conditions in order to fully describe call set-up.]

(*c*) Information paths are common highways linking the registers to the selection unit markers. In order to keep the holding time of the information path to a minimum, each information path comprises two independent groups of wires (known as *channels*), either of which may be engaged by a marker. Each channel consists of 20 wires, enabling fast interchange of two-out-of-five coded information in parallel. A sequence of operation, including seizure, signalling and guarding during release, is accomplished in approximately 130 ms.

Q4 *(a) Explain with the aid of a graph the effect of excessive line capacitance on the performance of loop/disconnect DC pulses.*

(b) For a modern long distance DC signalling system describe

(i) the principle of operation with the aid of a circuit element

(ii) how the signalling path is provided when line amplifiers are included on the route.

Q5 *For single-server delay call systems:*

(a) list two disadvantages of dispersing the calls in the queue at random compared with orderly queue dispersal.

(b) A common translator with an average holding time of 200 ms is offered 3000 busy hour calls. Calculate

(i) the probability of a call being delayed

(ii) the mean delay of all the calls

(c) explain the effect on the queue if more than one erlang of busy-hour traffic were offered to a translator.

A5 (*a*) For a single-server delay call system, two disadvantages of dispersing the calls in the queue at random compared with orderly queue dispersal are:

(*i*) As calls are served in a random manner, how quickly calls are served depends on luck since some callers could wait a long time to be served whilst others could be served quickly, independent of the order of arrival at the queue.

(*ii*) There is a tendency for callers waiting a long time to give up and try calling again, which tends to create false traffic.

(*b*) (*i*) The traffic offered in erlangs,

$$A = CH,$$

where C is the number of calls per hour, and H is the average holding time in hours.

$$\therefore \quad A = \frac{3000 \times 0{\cdot}2}{3600} = 0{\cdot}166 \text{ erlang}.$$

Now the probability of a call being delayed,

$$P = CH = A = \underline{0{\cdot}166}.$$

(*ii*) The mean delay of all the calls

$$= \frac{PH}{1 - A} = \frac{0{\cdot}166 \times 200}{1 - 0{\cdot}166} = \underline{39{\cdot}8 \text{ ms}}.$$

(*c*) In a waiting system, the traffic offered to the system must not exceed the traffic carrying capacity of the channels; that is, for a single server $A \leqslant 1$, where A is the traffic offered in erlangs. If this condition is not fulfilled, the queue would grow to an infinite size. Therefore, if more than one erlang of busy-hour traffic were offered to a translator, the queue could, in theory, grow to an infinite size; however, the immediate effect would be that calls in the queue would not be served.

Q6 *(a) For an automatic telephone exchange state*

(i) why a maintenance organisation is necessary

(ii) the main purpose of the artificial traffic equipment (ATE).

(b) Describe, with the aid of a block diagram, the principle of operation of the ATE, including the access arrangements.

(c) List two advantages of the ATE compared with the automatic routine tester (routiner).

Q7 *For a modern single-frequency (1 VF) inband signalling system*

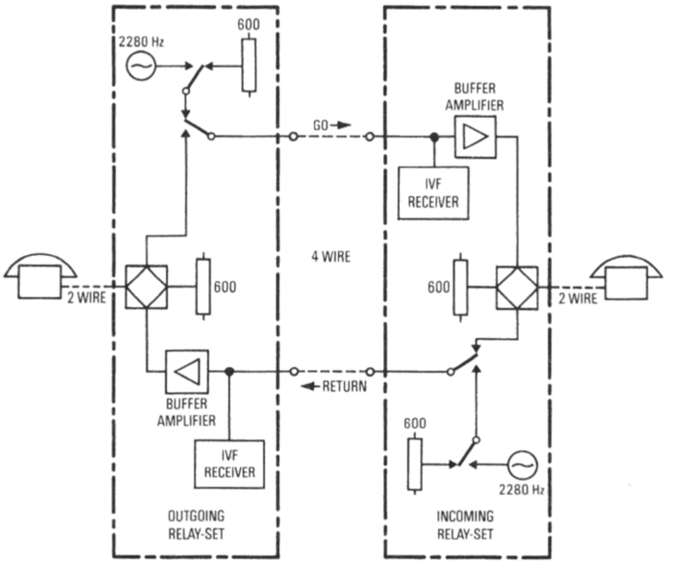
(a) draw and label a block diagram

(b) describe the functions of FOUR essential items in the answer in (a)

(c) list the various signals giving typical signal durations used in setting up and clearing down a call.

(d) explain the signal sequence that prevents a premature cleardown should a false clear signal occur in the circuit.

A7 (*a*) A block diagram of a 1 VF signalling system is shown in the sketch.



(*b*) The following four essential items are used in the 1 VF signalling system:

(*i*) *Hybrid transformer* This is necessary to convert the two-wire line into four and vice versa. The hybrid transformer passes speech signals from the two-wire circuit to the transmit pair and from the receive pair to the two-wire with little attenuation, whilst presenting maximum attenuation between the receive and transmit pairs of each end.
(*ii*) *Outgoing relay-set* DC signalling is converted to 2280 Hz tone signals of varying duration (only part of the circuitry is shown in the sketch).
(*iii*) *1 VF receiver* This converts signalling tone into the corresponding DC signal.
(*iv*) *Buffer amplifier* This prevents near-end interference with the VF receiver and prevents the 2280 Hz tone from 'spilling over' into other links in the connection.

(*c*) The following table lists the various signals and typical durations used in setting up and clearing down a call.

Direction	Signal	Duration (ms)
Forward	Seizure	65
	Digit pulse	60
	Forward clear	900
Backward	Answer	250
	Clear back	250
	Release guard	1000

(*d*) The incoming relay-set is associated with the VF receiver and this is designed to detect the various signals. In the event of a false *clear* signal, that is, a short break in the transmission path, the relay-set does not recognise this as a *clear* signal and the circuit remains connected.

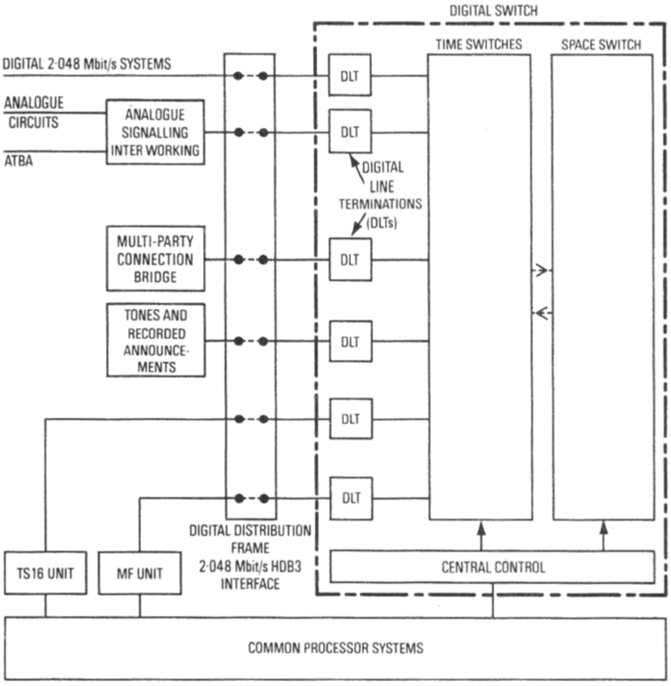
Q8 *(a) List four advantages of switching two pulse-code modulation (PCM) links at a digital tandem exchange compared with switching them at a space-division exchange.*
(b) For a typical digital tandem exchange

(i) draw and label a block diagram showing the main items of equipment including both space and time switching
(ii) explain how incoming and outgoing PCM channels are associated
(iii) describe how the incoming bit stream is rearranged to reduce the number of electronic crosspoints required.

A8 (*a*) Four advantages of switching two PCM links at a digital tandem exchange compared with switching them at a space-division exchange are as follows:

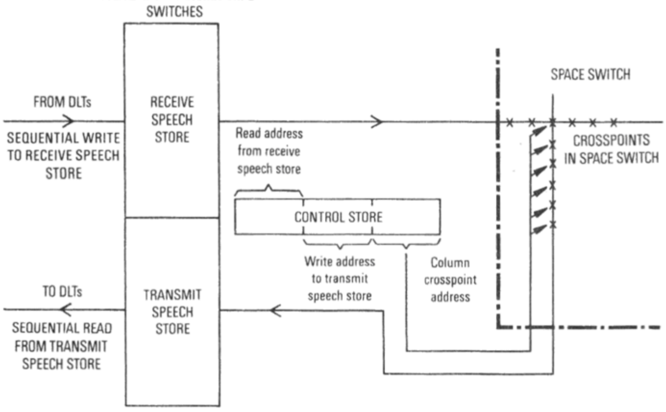
(*i*) intermediate primary multiplexing equipment and 'per-circuit' signalling equipment at the switching/transmission interface are eliminated; thus cost savings are made. For a 30-circuit PCM link, a common signalling path is provided.
(*ii*) A considerable reduction in the number of crosspoints is achieved.
(*iii*) Digital switching is inherently non-blocking; that is, all inlets have access to outlets.
(*iv*) A through digital connection of 64 kbit/s is achieved, which can be used for high-speed data transmission.

(*b*) (*i*) A block diagram of a digital tandem exchange is given in sketch (*a*).


DIGITAL SWITCH
TIME SWITCHES
SPACE SWITCH
DIGITAL 2·048 Mbit/s SYSTEMS
ANALOGUE CIRCUITS
ATBA
ANALOGUE SIGNALLING INTER WORKING
DLT
DLT
DIGITAL LINE TERMINATIONS (DLTs)
MULTI-PARTY CONNECTION BRIDGE
DLT
TONES AND RECORDED ANNOUNCE-MENTS
DLT
DLT
DLT
DIGITAL DISTRIBUTION FRAME
2·048 Mbit/s HDB3 INTERFACE
TS16 UNIT
MF UNIT
CENTRAL CONTROL
COMMON PROCESSOR SYSTEMS

(*a*)

(*ii*) An incoming PCM channel is associated with an outgoing PCM channel by the time-space-time (TST) digital switch. The organisation of a typical TST digital switch is shown in sketch (*b*).


RECEIVE AND TRANSMIT TIME-SWITCHES
FROM DLTs
SEQUENTIAL WRITE TO RECEIVE SPEECH STORE
RECEIVE SPEECH STORE
Read address from receive speech store
CONTROL STORE
Write address to transmit speech store
Column crosspoint address
SPACE SWITCH
CROSSPOINTS IN SPACE SWITCH
TO DLTs
SEQUENTIAL READ FROM TRANSMIT SPEECH STORE
TRANSMIT SPEECH STORE

(*b*)

In sketch (*b*), PCM systems are terminated on digital line terminations (DLTs). The DLT transmits 8 bit speech samples with an additional parity bit to a receive time switch, and receives information from a receive time switch. The function of the time switch is to receive a speech sample, delay it and forward it to another time-slot. This is achieved by writing it into a store and reading it out at a later time. The time switch has two stores: a speech store which holds one frame of speech samples, and a control store which specifies the time-slot interconnections. There is one location in the control store for each time-slot of the space switch multiplex. The location contains the address within the receive speech store to be transmitted to the row of crosspoints, the address of the crosspoint in the column to be closed, and the address in the transmit speech store where the received sample should be written.

The space switch consists of two 9 bit parallel highways operating at

8·192 Mbit/s, to pass information to and from the time-divided space switch.

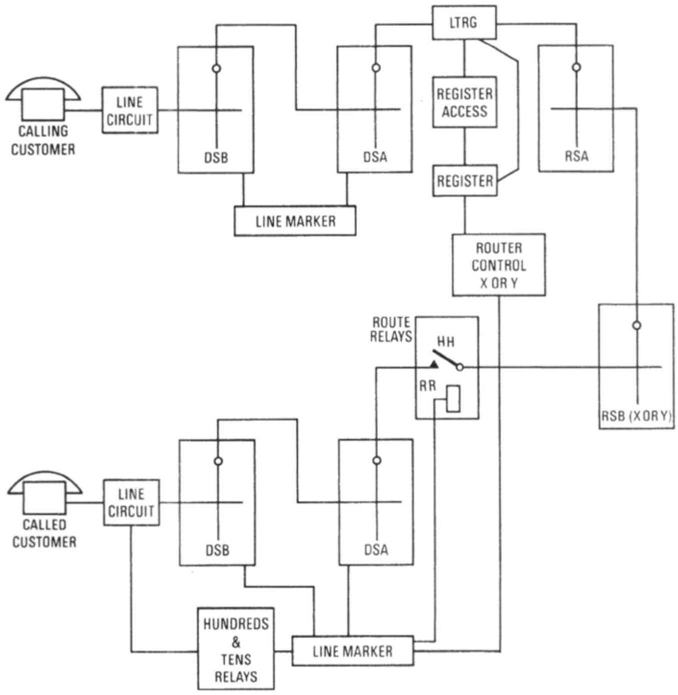
(*iii*) In the system described above, up to 32 DLTs (a total of 1024 channels) can be connected to each receive and transmit time switch. The receive and transmit time switches each have a speech store comprising 1024 locations. Speech samples are transferred sequentially between a DLT and the speech stores; however transfers between the speech stores and the space switch operate at 8·192 Mbit/s. This process of parallel to serial conversion enables the number of crosspoints to be reduced, since each crosspoint handles 1024 time-slots every 120 μs.

Q9 *For the 5005 crossbar and the large reed electronic (TXE4 or equivalent) exchanges*

(a) draw and label a diagram showing speech paths for local calls. Include in the diagram the various switching stages and the location of transmission bridges

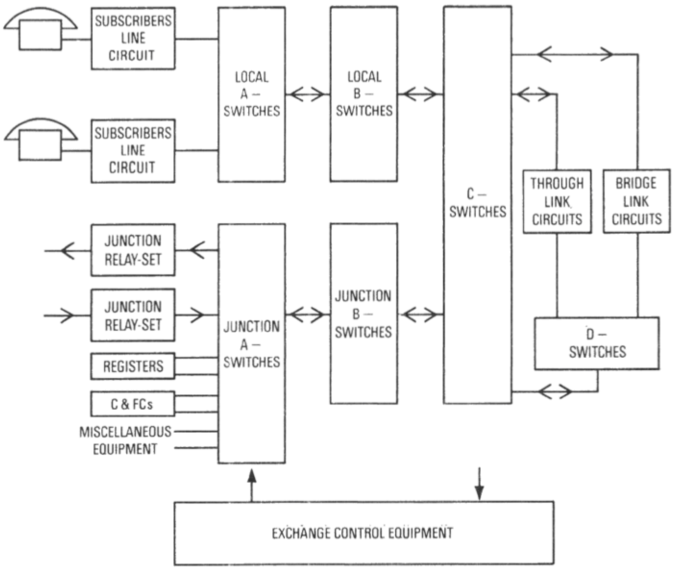
(b) describe how the concentration stage is modified in each case to take into account different calling rates.

A9 (*a*) (*i*) Sketch (*a*) gives a block diagram of the equipment used in setting up a local call in a 5005 crossbar (TXK1) exchange.



(*a*)

(*ii*) Sketch (*b*) gives a block diagram of the equipment used in setting up a local call in a TXE4 exchange.



(*b*)

(*b*) (*i*) For a 5005 crossbar exchange, the distributor contains two ranks of crossbar switches: distributor switches A (DSAs) and distributor switches B (DSBs). Each DSB can cater for 25 line circuits and there are 20 DSBs in all; one distributor therefore can accommodate 500 customers' lines (20 × 25). An exchange of 2000 lines would require 4 distributors. The number of DSAs within a distributor ranges from 6 to 16 depending on the customer calling rate. If the number exceeds 8, the extra switches are parallel to the existing switches in such a way as to give the same number of outlets, but double the number of inlets; thus, if 16 DSAs are needed, there would be $16 \times 10 = 160$ inlets and $8 \times 25 = 200$ outlets.

(*ii*) For a description of the method of concentration for TXE4, see A3, part (*ii*), Switching T4 Option (1985), *Supplement*, Vol. 4, Part 4, p. 48, Jan. 1986.

Q10 *(a) State* TWO *reasons for recording traffic at an automatic telephone exchange.*

(b) With the aid of a circuit element explain the principle of operation of an automatic traffic recorder (ATR).

(c) 1000 registrations are recorded on a traffic meter during a time consistent busy hour traffic record on long holding time equipment over a period of five days. Calculate

(i) the average busy hour traffic in erlangs carried by the equipment

(ii) the number of registrations if the same amount of traffic were carried by short holding time equipment during the same period.

Answers contributed by J. Bush

BUSINESS AND TECHNICIAN EDUCATION COUNCIL

National Certificate in Telecommunications

Sets of model questions and answers for Business and Technician Education Council (BTEC) units are given below. The questions illustrate the types of questions that students may encounter, and are useful as practice material for the skills learned during the course.

Where additional text is given for educational purposes, it is shown within square brackets to distinguish it from information expected of students under examination conditions. Representative time limits for questions are shown, and care has been taken to give model answers that reflect these limits.

We would like to emphasise that the questions are not representative of questions set by any particular college.

BTEC: ELECTRICAL AND ELECTRONIC PRINCIPLES II

The questions in this paper are based on the BTEC's standard unit U81/747. Students are advised to read the notes above

Q1 Determine the value of the current flowing in the 6 Ω resistor and the voltage developed across the 4 Ω resistor in Fig. 1. *(5 min)*

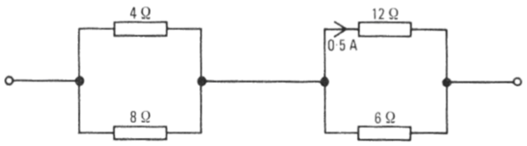


Fig. 1

A1 The voltage drop across the 12 Ω resistor is given by

$$0{\cdot}5 \times 12 = 6\,\text{V}.$$

This voltage is also developed across the 6 Ω resistor since the 6 Ω and 12 Ω resistors are in parallel.

Thus, the current in the 6 Ω resistor is given by

$$\frac{6\,\text{V}}{6\,\Omega} = \underline{1\,\text{A}.}$$

The total current in the 6/12 Ω parallel circuit $= 0{\cdot}5 + 1 = 1{\cdot}5$ A.

This is also the total current of the 4/8 Ω parallel circuit.

The voltage developed across the 4 Ω resistor = voltage developed across the 4/8 Ω parallel circuit.

The voltage developed across the 4 Ω resistor $= 1{\cdot}5\,\text{A} \times R$, where $R = \dfrac{4 \times 8}{4 + 8} = 2{\cdot}67\,\Omega$.

Thus, the voltage developed across the 4 Ω resistor $= 1{\cdot}5 \times 2{\cdot}67 = \underline{4\,\text{V}.}$

Q2 The power dissipated in the 18 Ω resistor in Fig. 2 is given as 3 W. Determine the total power dissipated by the circuit. *(5 min)*

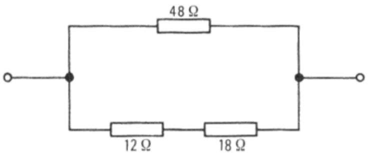


Fig. 2

A2 If I is the current in the 18 Ω resistor,

$$3 = I^2 \times 18.$$

$$\therefore \quad I^2 = 0{\cdot}167.$$

$$\therefore \quad I = 0{\cdot}41\,\text{A}.$$

This current also flows in the 12 Ω resistor; thus, the power dissipated in 12 Ω resistor

$$= I^2 \times 12 = 0{\cdot}167 \times 12 = 2\,\text{W}.$$

The potential difference, V, across the 48 Ω resistor

$$\begin{aligned} &= \text{potential difference across the 12/18 } \Omega \text{ network}, \\ &= I(12 + 18), \\ &= 0{\cdot}41 \times 30, \\ &= 12{\cdot}3\,\text{V}. \end{aligned}$$

The power dissipated in the 48 Ω resistor

$$= \frac{V^2}{48} = \frac{151{\cdot}29}{48} = 3{\cdot}15\,\text{W}.$$

Therefore, the total power dissipated by the circuit

$$= 3 + 2 + 3{\cdot}15 = \underline{8{\cdot}15\,\text{W}.}$$

Q3 Determine, by means of Kirchhoff's laws, the total power dissipated by the circuit in Fig. 3. *(8 min)*

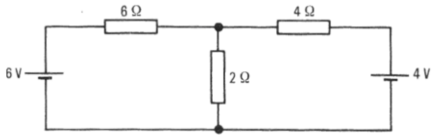
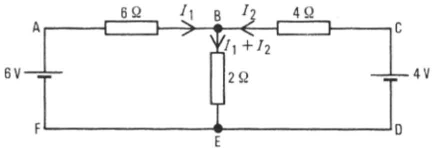


Fig. 3

A3 See sketch. The current directions shown are assumed.



For loop ABEFA,

$$\begin{aligned} 6 &= 6I_1 + 2I_1 + 2I_2, \\ &= 8I_1 + 2I_2. \qquad \ldots\ldots(1) \end{aligned}$$

For loop CBEDC,

$$\begin{aligned} 4 &= 2I_1 + 2I_2 + 4I_2, \\ &= 2I_1 + 6I_2. \qquad \ldots\ldots(2) \end{aligned}$$

Multiplying equation (2) by 4 gives

$$16 = 8I_1 + 24I_2. \qquad \ldots\ldots(3)$$

Subtracting equation (1) from equation (3) gives

$$\begin{aligned} 16 &= 8I_1 + 24I_2. \\ 6 &= 8I_1 + 2I_2. \\ \hline 10 &= 22I_2. \end{aligned}$$

$$\therefore \quad I_2 = \frac{10}{22} = 0{\cdot}45\,\text{A}.$$

Substituting in equation (1) gives

$$\begin{aligned} 6 &= 8I_1 + (2 \times 0{\cdot}45), \\ &= 8I_1 + 0{\cdot}9. \\ \therefore \quad 8I_1 &= 6 - 0{\cdot}9, \\ &= 5{\cdot}1. \\ \therefore \quad I_1 &= \frac{5{\cdot}1}{8}, \\ &= 0{\cdot}64\,\text{A}. \end{aligned}$$

As no negative values of current were obtained, the direction of the current flows shown are therefore correct.

The current in the 6 Ω resistor = $I_1 = 0{\cdot}64$ A.
The current in the 4 Ω resistor = $I_2 = 0{\cdot}45$ A.
The current in the 2 Ω resistor = $I_1 + I_2 = 1{\cdot}09$ A.
The total power dissipated by the circuit

$$= I_1^2 \times 6 + I_2^2 \times 4 + (I_1 + I_2)^2 \times 2,$$

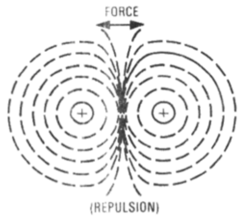
$$= 2{\cdot}46 + 0{\cdot}81 + 2{\cdot}38,$$

$$= \underline{5{\cdot}65\ W.}$$

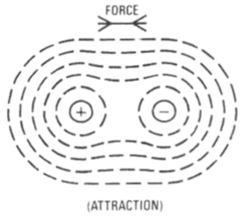
Q4 Sketch the electric fields, and the resultant direction of force, of two adjacent charged bodies when

(a) both bodies are positively charged, and
(b) one body is positively charged and the other negatively charged. *(3 min)*

A4



(a)



(b)

Q5 If one proton has a charge of $1{\cdot}6 \times 10^{-19}$ *C,*

(a) how much charge has one electron, and
(b) how much charge has one neutron? *(1 min)*

A5 (a) An electron charge is exactly opposite to a proton charge; thus an electron has a charge of $-1{\cdot}6 \times 10^{-19}$ C.
(b) A neutron has no charge.

Q6 Two parallel plates are separated by a dielectric 0·02 mm thick. If the electric field strength is 50 kV/m, determine the applied voltage. *(2 min)*

A6 The electric field strength,

$$E = \frac{\text{applied voltage}}{\text{distance between plates}}.$$

Therefore, the applied voltage

$$= 50 \times 10^3 \times 0{\cdot}02 \times 10^{-3} = \underline{1{\cdot}0\ \text{V}.}$$

Q7 A 2 μF capacitor is charged with a constant current of 2 mA for 2·5 ms. Determine the potential difference between the plates of the capacitor. *(3 min)*

A7 If a current I is applied for t seconds, then the charge on the capacitor, $Q = It$ coulombs. But $Q = CV$, where V is the potential difference between the plates.

$$\therefore \quad V = \frac{Q}{C} = \frac{It}{C},$$

$$= \frac{2 \times 10^{-3} \times 2{\cdot}5 \times 10^{-3}}{2 \times 10^{-6}},$$

$$= \underline{2{\cdot}5\ \text{V}.}$$

Q8 Determine the overall capacitance of the circuit shown in Fig. 4. *(3 min)*

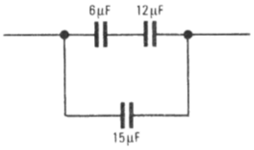


Fig. 4

A8 Let the capacitance of the series 6/12 μF network be C_p.

$$\frac{1}{C_p} = \frac{1}{6} + \frac{1}{12} = \frac{3}{12}.$$

$$\therefore \quad C_p = \frac{12}{3} = 4\ \mu\text{F}.$$

The total capacitance of the circuit

$$= 4 + 15 = \underline{19\ \mu\text{F}.}$$

Q9 Explain the term 'reluctance' in magnetism. *(3 min)*

A9 The magnetic resistance of a particular magnetic circuit to the presence of magnetic flux is called the *reluctance* of the magnetic circuit.
Reluctance, S, is given by the formula

$$S = \frac{F}{\Phi}\ \text{henrys}^{-1}$$

where F is the magnetomotive force, and Φ is the magnetic flux.

Q10 State the units of the following magnetic terms:

(a) flux density,
(b) field strength, and
(c) permeability. *(1 min)*

A10 (a) Tesla (T),
(b) amperes/metre (A/m), and
(c) henrys/metre (H/m).

Q11 A coil has 4000 turns of wire wound on a silicon steel magnetic circuit. If the length of the magnetic circuit is 15 cm and the coil carries a current of 20 mA, find the flux density in the steel. Let the absolute permeability of silicon steel be 1·3 mH/m. *(3 min)*

A11 Let N be the number of turns of wire (4000),
L be the length of the magnetic circuit (15 cm),
I be the current (20 mA),
μ be the absolute permeability of steel (1·3 mH/m), and
H be the field strength.

Then,

$$H = \frac{NI}{L}\ \text{amperes/metre},$$

and

$$B = \mu H.$$

Thus,

$$B = \mu \frac{NI}{L},$$

$$= 1{\cdot}3 \times 10^{-3} \times \frac{4000 \times 20 \times 10^{-3}}{15 \times 10^{-2}},$$

$$= \underline{0{\cdot}693\ \text{T}.}$$

Q12 Discuss the magnetic requirements of materials for permanent magnets. *(3 min)*

A12 Materials used for permanent magnets need to have high remanence, typically 1 T, and high coercivity, typically 50 000 A/m. These materials are known as being *magnetically hard*.

Q13 Fig. 5 shows a typical magnetising curve for soft iron. What value of permeability does the X–Y region represent? *(1 min)*

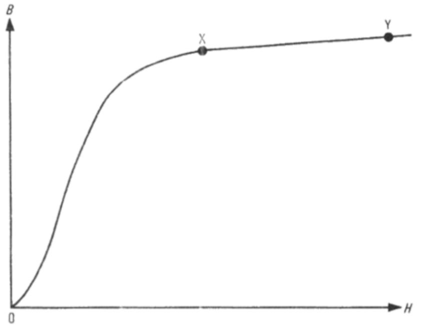


Fig. 5

A13 The X–Y region is the saturation region, and the slope of the curve in this region represents the permeability of free space.

Q14 *A conductor has an active length of 0·2 m and moves in a magnetic field at a linear velocity of 150 m/s. If the magnetic flux density is 0·01 T, calculate the average value of the induced EMF if the direction of movement is*

(a) perpendicular to the field, and
(b) at 45° to the direction of the field. *(4 min)*

A14 Let B be the flux density (0·01 T),
L be the length of the conductor (0·2 m), and
v be the velocity (150 m/s).

(*a*) The induced EMF

$$= BLv = 0{\cdot}01 \times 0{\cdot}2 \times 150,$$

$$= \underline{0{\cdot}3\ \text{V}}.$$

(*b*) The induced EMF

$$= BLv \sin 45^\circ = 0{\cdot}3 \times 0{\cdot}707,$$

$$= \underline{0{\cdot}21\ \text{V}}.$$

Q15 *A conductor, located within a magnetic field, carries a current of 25 A. If the active length of the conductor is 0·35 m and it experiences a force of 15 N due to the magnetic field, find the value of the flux density of the field.* *(3 min)*

A15 Let L be the length of the conductor (0·35 m),
I be the current (25 A),
F be the force (15 N), and
B be the flux density in tesla.

$$F = BLI$$

$$\therefore \quad B = \frac{F}{LI} = \frac{15}{0{\cdot}35 \times 25},$$

$$= \underline{1{\cdot}7\ \text{T}}.$$

Q16 *A current in a coil changes from 40 mA to 15 mA in 4 ms. If the inductance of the coil is 5 mH and the number of turns in the coil is 250, determine the resultant change in flux.* *(3 min)*

A16 Let Δi be the change in current (25 mA),
Δt be the change in time (4 ms),
L be the inductance of the coil (5 mH),
N be the number of turns, and
$\Delta\Phi$ be the change in flux.

$$L\frac{\Delta i}{\Delta t} = N\frac{\Delta\Phi}{\Delta t}.$$

$$\Delta\Phi = \frac{L}{N}\Delta i,$$

$$= \frac{5 \times 10^{-3} \times 25 \times 10^{-3}}{250},$$

$$= \underline{0{\cdot}5\ \mu\text{Wb}}.$$

Q17 *A transformer carries a current of 500 mA in its primary winding. As a result, the secondary winding delivers a voltage of 12 V to a load of 200 Ω.*

(a) Determine the turns ratio.
(b) If the primary winding has 150 turns, how many turns are in the secondary winding?
(c) Determine the primary voltage. *(6 min)*

A17 The current delivered to the load

$$= \frac{12}{200} = 60\ \text{mA}.$$

(*a*) The turns ratio $= \dfrac{60}{500} = \underline{6{:}50}.$

(*b*) For every 6 turns in the primary, there are 50 turns in the secondary; thus, the number of turns in the secondary

$$= \frac{50}{6} \times 150 = \underline{1250}.$$

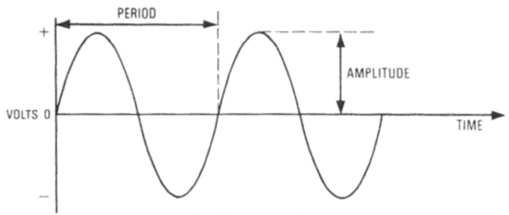
(*c*) $$\frac{\text{Primary voltage}}{\text{secondary voltage}} = \frac{\text{number of turns in the primary}}{\text{number of turns in the secondary}}.$$

Thus, the primary voltage

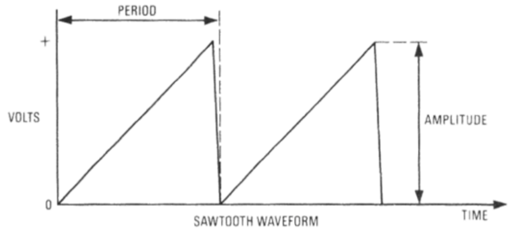
$$= 12 \times \frac{150}{1250} = \underline{1{\cdot}44\ \text{V}}.$$

Q18 *Sketch two cycles of a sinusoidal voltage waveform and a sawtooth voltage waveform. In each case indicate on your sketch: (a) the amplitude of the wave; (b) the period of the wave.* *(4 min)*

A18



SINUSOIDAL WAVEFORM



SAWTOOTH WAVEFORM

Q19 *A sinusoidal voltage has a peak value of 4 V and a frequency of 200 Hz. Determine the instantaneous value of the voltage at t = 0·2 ms.* *(3 min)*

A19 The instantaneous voltage, v, at time t is given by

$$v = V_\text{m} \sin \omega t,$$

where V_m is the peak voltage and $\omega = 2\pi \times$ frequency.
Thus,

$$v = 4 \times \sin(2\pi \times 200 \times 0{\cdot}2 \times 10^{-3}),$$

$$= 4 \times \sin 0{\cdot}25,$$

$$= \underline{0{\cdot}995\ \text{V}}.$$

Q20 *A sinusoidal voltage, v = 3 sin 2000πt, is applied to a load of 540 Ω. Determine the power dissipated in the load and the RMS current flowing in the load.* *(4 min)*

A20 The peak voltage = 3 V.
The RMS voltage = 3 × 0·707 = 2·121 V.

Thus, the RMS current in the load $= \dfrac{2{\cdot}121}{540} = \underline{3{\cdot}93\ \text{mA}}.$

The power dissipated in the load $= I^2R$, where I is the RMS current and R the load resistance.

Thus, the power $= 3{\cdot}93^2 \times 10^{-6} \times 540,$

$$= \underline{8{\cdot}34\ \text{mW}}.$$

Q21 *A voltage of 6 V at 45 kHz is applied across an inductor. As a result, a current of 1·5 mA flows in the inductor.*

(a) Determine the reactance of the inductor.
(b) Determine the inductance of the inductor.

Assume an ideal inductor. *(4 min)*

A21 (*a*) Reactance of the inductor

$$= \frac{\text{voltage}}{\text{current}} = \frac{6}{1{\cdot}5 \times 10^{-3}} = \underline{4000\,\Omega}.$$

(*b*) The reactance of the inductor

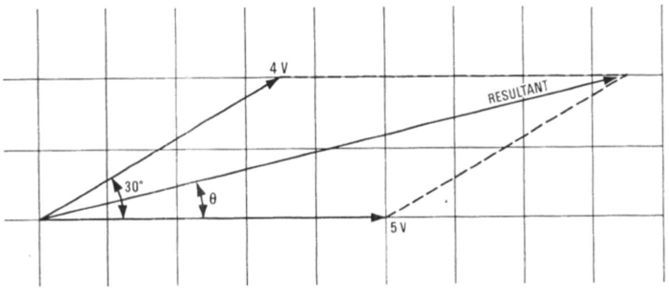
$$= 2\pi \times \text{frequency} \times \text{inductance}.$$

Thus,

$$\text{inductance} = \frac{4000}{2\pi \times 45\,000} = \underline{14{\cdot}15\text{ mH}}.$$

Q22 *Two voltages, having the same frequency, have amplitudes of 4 V and 5 V respectively. If the 4 V wave leads the 5 V wave by 30°, determine, by scaled phasor diagram, the resultant voltage and its angle relative to the 5 V wave, when both are applied to the same load.* (*6 min*)

A22

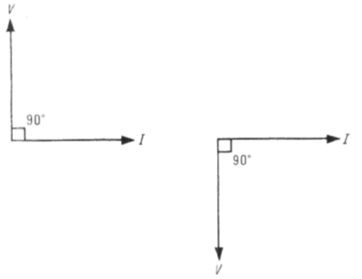


From the scaled diagram, the resultant voltage is 8·7 V, and leads the 5 V wave by 13°.

Q23 *Sketch typical phasor diagrams for the voltage and current of a pure*

(*a*) *inductor, and*
(*b*) *capacitor.* (*2 min*)

A23



(*a*) Inductor (*b*) Capacitor

Q24 *A voltage of 5 V is applied across a series resistor/capacitor circuit. If the frequency of the voltage is 30 kHz, the resistor has a value of 400 Ω and the capacitor has a capacitance of 0·02 μF, find*

(*a*) *the overall impedance of the circuit, and*
(*b*) *the phase angle between the applied voltage and the supply current.* (*4 min*)

A24 (*a*) The reactance of the capacitor at frequency *f*

$$= \frac{1}{2\pi f C} = \frac{1}{2\pi \times 30 \times 10^{3} \times 2 \times 10^{-8}} = 265\,\Omega.$$

The overall impedance

$$= \sqrt{(400^2 + 265^2)} = \underline{480\,\Omega}.$$

(*b*) If θ is the phase angle and X_C the reactance of the capacitor,

$$\tan\theta = \frac{X_C}{R}.$$

$$\therefore \quad \theta = \tan^{-1}\left(\frac{265}{400}\right),$$

$$= \tan^{-1} 0{\cdot}6625,$$

$$= 33{\cdot}5°.$$

Therefore, the phase angle is 33·5°, with the supply current leading the supply voltage.

Q25 *A series LCR circuit has the following values:*

$$L = 5\text{ mH} \qquad C = 4\,\mu F \qquad R = 10\,\Omega.$$

(*a*) *Determine the resonant frequency of the circuit.*
(*b*) *If the current drawn from the supply at resonance is 0·2 mA, determine the power dissipated by the circuit.* (*5 min*)

A25 (*a*) At the resonant frequency, f_0, the reactance of the inductor, X_L, is equal to the reactance of the capacitor, X_C.

$$2\pi f_0 L = \frac{1}{2\pi f_0 C}.$$

$$\therefore \quad f_0 = \frac{1}{2\pi\sqrt{(LC)}},$$

$$= \frac{1}{2\pi\sqrt{(5 \times 10^{-3} \times 4 \times 10^{-6})}},$$

$$= \underline{1125\text{ Hz}}.$$

(*b*) The power dissipated by the circuit is the power dissipated in the resistor

$$= I^2R = (0{\cdot}2 \times 10^{-3})^2 \times 10 = \underline{0{\cdot}4\,\mu\text{W}}.$$

Q26 *A series LCR circuit resonates at 25 kHz. If L = 0·3 mH, C = 0·001 μF and R = 5 Ω, determine the Q factor of the circuit.* (*3 min*)

A26 If f_0 is the resonant frequency, then the Q factor

$$= \frac{2\pi f_0 L}{R} = \frac{2\pi \times 25 \times 10^{3} \times 0{\cdot}3 \times 10^{-3}}{5},$$

$$= \underline{9{\cdot}4}.$$

Q27 *In a series LR AC circuit, the power dissipated by the circuit is 2 W. If the phase angle of the supply is 15° determine the apparent power of the circuit.* (*2 min*)

A27 The true power = apparent power × cos ϕ, where ϕ is the phase angle of the supply.

Therefore, the apparent power

$$= \frac{\text{true power}}{\cos\phi} = \frac{2}{\cos 15°} = \underline{2{\cdot}07\text{ V A}}.$$

Q28 *A series LCR circuit has the following values:*

$$L = 2{\cdot}0\text{ mH} \qquad C = 1{\cdot}0\,\mu F \qquad R = 40\,\Omega.$$

Determine the impedance of the circuit when it is supplied with an AC current at a frequency of 2000 Hz. (*5 min*)

A28 The impedance,

$$Z = \sqrt{\{R^2 + (X_L - X_C)^2\}},$$

where, at frequency *f*,

$$X_L = 2\pi f L = 2\pi \times 2000 \times 2 \times 10^{-3} = 25{\cdot}13\,\Omega,$$

and

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 2000 \times 10^{-6}} = 79{\cdot}58\,\Omega.$$

$$\therefore \quad Z = \sqrt{(40^2 + 54{\cdot}45^2)} = \underline{67{\cdot}56\,\Omega}.$$

Q29 *A series RC circuit has a reactive power of 24 var. If the apparent power is 28 V A, determine the phase angle of the supply.*

A29 The apparent power = $VI = 28$ V A.
The reactive power = $VI \sin\phi = 24$ var.

$$\therefore \quad \sin\phi = \frac{24}{28} = 0{\cdot}86.$$

$$\therefore \quad \phi = \underline{59{\cdot}3^\circ}.$$

Q30 Describe, in terms of the valence and conduction energy bands, the electrical properties of a material. *(6 min)*

A30 The ease with which an electron moves from the valence band to the conduction band is a measure of the conductivity of the material. In a conductor material, the valence and conduction energy bands overlap and therefore the material has a large density of 'free' electrons.

In an insulator material, the energy gap between the valence and conduction bands is very large; thus very few 'free' electrons exist in the material. To raise an electron from the valence band to the conduction band would, in many cases, cause so much energy to be dissipated that the material would be destroyed.

A semiconductor has a small energy gap between the valence and conduction bands, and its electrical properties lie between that of a conductor and an insulator.

Q31 Explain the semiconductor term 'hole'. *(2 min)*

A31 A hole is said to exist in the atomic structure of a semiconductor material when the space occupied by an electron is vacated by that electron. When an electron occupies a hole, hole/electron pairing is said to have taken place.

Q32 Silicon, relatively, is more adversely affected by temperature changes than germanium. Explain why silicon is still preferred, in many applications, to germanium. Quote typical conduction changes due to temperature changes. *(8 min)*

A32 At room temperature, each increase of 10°C roughly doubles the minority carriers of germanium. However, at room temperature, each increase of 5°C roughly doubles the minority carriers of silicon.

Minority carriers can adversely influence the operation of a circuit. A germanium p n junction, when reverse biased, has a reverse current of a few microamperes flowing across it. This current is large enough generally to generate noise in the system. If the temperature should increase, the effect of this reverse current becomes more noticeable.

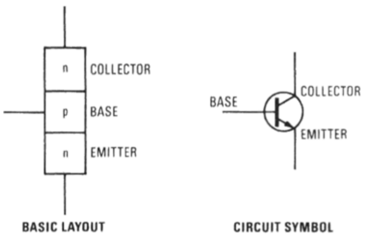
A silicon p n junction, when reverse biased, has a reverse current of a few nanoamperes flowing across it. This current is generally too small to generate noise in the system. Increases in temperature increase this reverse current but, as its level is still in the nanoampere range, noise is less of a problem compared with that for germanium.

Q33 What condition reduces the depletion layer region of a p n junction? *(1 min)*

A33 A forward-bias condition.

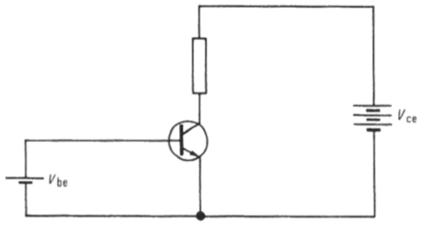
Q34 Explain the basic principles of operation of an n p n transistor. Include elementary diagrams. *(10 min)*

A34 An n p n transistor comprises two n-type segments sandwiching a p-type segment (see sketch (*a*)). Although sketch (*a*) shows the p-type segment being as large as the n-type segments, it is in fact very narrow.



(*a*)

To function correctly, the base/emitter junction must be forward biased and the base/collector junction reverse biased. To obtain these conditions, external power supplies are connected to the transistor (see sketch (*b*)).



(*b*)

V_{be} provides the forward biasing of the base/emitter junction and, as V_{ce} is a much larger value than V_{be}, the base/collector junction is effectively reverse biased. The biasing of a p n junction influences the flow of majority current carriers across that junction; the minority current carriers however are not influenced by the biasing condition.

In the circuit shown, the V_{be} supply injects current (holes) into the base region. These holes attract electrons from the emitter region and the electrons cross over the forward biased p n junction in large numbers in order to combine with the holes. Some of the electrons flowing into the base region combine with the holes. The remaining electrons in the base region are in effect minority current carriers, as the base region is of p-type material. These minority current carriers are drawn across the base/collector junction by the high positive potential on the collector. The amount of electrons which combine with the holes in the base region compared with the amount of electrons which cross over into the collector region is of the order 1:200.

The transistor is therefore a current-operated device relying on both minority and majority current carriers to effect operation; and its forward current gain (h_{fe}) is typically 200.

Q35 A moving-coil meter gives a full-scale deflection at 10 mA. If the resistance of the coil is 4 Ω, determine the resistance of the shunt required to give full-scale deflection when the circuit current is 5 A. *(3 min)*

A35 Let I_g be the full-scale deflection current (10 mA), and R_g be the resistance of the coil (4 Ω). The shunt current, S

$$= 5\text{ A} - 10\text{ mA} = 4{\cdot}99\text{ A}.$$

Therefore, the shunt resistance required

$$= \frac{I_g R_g}{S} = \frac{10 \times 10^{-3} \times 4}{4{\cdot}99} = 0{\cdot}008\ \Omega.$$

Q36 The following conditions are to be monitored on the circuit shown in Fig. 6:

(a) AC input current to transistor TR1,
(b) DC voltage of resistor R1,
(c) DC current of transistor TR2, and
(d) the supply voltage.

Sketch in the relevant meters.

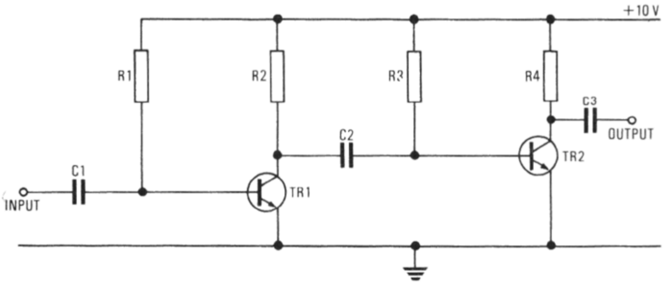
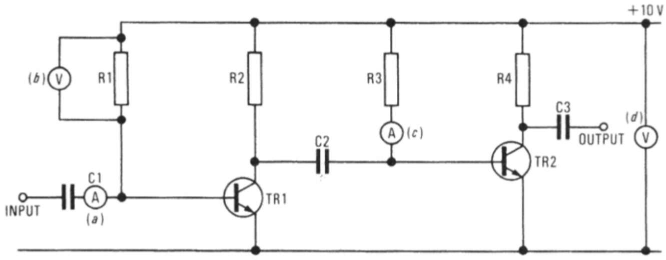


Fig. 6

A36



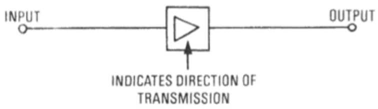
Questions and answers contributed by N. C. Webber

BTEC: TRANSMISSION SYSTEMS II

The following questions are based on the BTEC's standard unit U81/746. Students are advised to read the notes on p. 77

Q1 Draw a standard block diagram symbol for an amplifier and explain how it is used in a 4-wire amplified telephone circuit. (5 min)

A1 See sketch.



An amplifier is a one-way device; that is, it amplifies in one direction of transmission. To obtain amplification of speech in both directions of a telephone circuit, it is necessary to provide two separate amplifiers and circuits. One circuit is for speech from the originating telephone to the distant end; this is known as the *transmit* amplified circuit. The other circuit is used for the speech coming from the distant end; this is known as the *receive* amplified circuit.

The transmit and receive directions of transmission make up the 4-wire amplified circuit.

Q2 State the three functions of a 4-wire terminating unit. (3 min)

A2 (*a*) To allow speech signals to be transferred from the 2-wire to the transmit of the 4-wire.

(*b*) To allow speech signals to be transferred from the receive of the 4-wire to the 2-wire.

(*c*) To prevent speech signals from being transferred from the receive of the 4-wire to the transmit of the 4-wire.

Q3 Explain briefly the term 'howling'. (3 min)

A3 Howling is uncontrolled oscillations which occur when the output of one amplifier is allowed to pass at a high level to the input of the amplifier in the opposite direction of transmission on a 4-wire amplified circuit.

Q4 State the number of speech channels which can be accommodated on the following coaxial systems. Also state which systems can carry a 625-line television system.

(*a*) *60 MHz system*
(*b*) *12 MHz system*
(*c*) *4 MHz system.*

A4 (*a*) 10 800 speech channels or one 625-line television channel plus several thousand speech circuits.

(*b*) 2700 speech channels or one 625-line television channel plus several hundred speech circuits.

(*c*) 960 speech channels.

[*Tutorial Note:* One 625-line television channel occupies a bandwidth of 0–5·5 MHz.]

Q5 Select from the key below the baseband frequencies of the following types of signals:

(*a*) *good-quality music,*
(*b*) *commercial speech, and*
(*c*) *625-line television.*

KEY:

(*i*) *30–300 Hz*
(*ii*) *300–3400 Hz*
(*iii*) *0–10 000 Hz*
(*iv*) *50–10 kHz*
(*v*) *50–550 kHz*
(*vi*) *0–5500 kHz*
(*vii*) *0–55 MHz*

(2 min)

A5 (*a*) (*iv*) 50–10 kHz
(*b*) (*ii*) 300–3400 Hz
(*c*) (*vi*) 0–5500 kHz.

Q6 The velocity of light in free space is known as 'c'.

(*a*) *State its value, and*
(*b*) *explain briefly what happens to this velocity in a cable.* (2 min)

A6 (*a*) 3×10^8 m/s.

(*b*) The velocity of propagation in a cable is always less than *c*.

Q7 (a) State the relationship between the frequency, wavelength and velocity of an electromagnetic wave in free space.

(b) Calculate the wavelength of a radio wave of frequency 600 kHz in free space. (3 min)

A7 (*a*) Velocity = frequency × wavelength.

(*b*) Velocity in free space (*c*) = frequency × wavelength (λ).

$$\therefore \quad 3 \times 10^8 = 600 \times 10^3 \lambda.$$

$$\therefore \quad \lambda = \frac{3 \times 10^8}{6 \times 10^5} = 0{\cdot}5 \times 10^3 = 500\,\text{m}.$$

Q8 The BBC Radio 4 Station operates at 1500 m long wave. What is its frequency? (3 min)

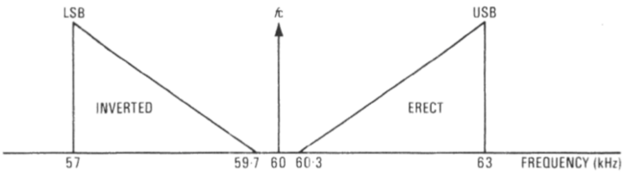
A8

$$\text{Frequency} = \frac{\text{velocity}}{\text{wavelength}}\ \text{Hz},$$
$$= \frac{3 \times 10^8}{1{\cdot}5 \times 10^3},$$
$$= \underline{2 \times 10^5\,\text{Hz}}, \quad \text{or} \quad \underline{200\,\text{kHz}}.$$

Q9 Draw a frequency spectrum diagram showing the following

(*a*) *a carrier, f_c, of 60 kHz,*
(*b*) *the upper and lower sidebands produced with a modulating frequency of 300–3 kHz, and*
(*c*) *an indication of the erect and inverted sidebands.* (4 min)

A9



[*Tutorial Note:* LSB is the lower sideband and USB is the upper sideband; these are bands of frequency equally spaced either side of the carrier frequency. The inverted sideband is so called because the highest frequency in it corresponds to the lowest modulating frequency. The erect sideband is so called because the lowest frequency in it corresponds to the lowest modulating frequency.]

Q10 (a) Explain the term 'percentage modulation' (also called 'depth of modulation').

(b) Calculate the magnitude of an unmodulated carrier if the variation that takes place due to modulation is 4 V and the percentage modulation is 80%. (5 min)

A10 (*a*) The amount of variation of carrier amplitude which takes place due to modulation can be expressed as a percentage. This is known as *percentage modulation.*

(*b*) If *A* is the magnitude of the unmodulated carrier (that is, the magnitude when the modulating voltage is zero), and *B* the variation that takes place, then

$$\text{the percentage modulation} = \frac{B}{A} \times 100\%.$$

$$\therefore \quad 80 = \frac{4}{A} \times 100,$$

$$\therefore \quad A = \frac{4}{80} \times 100,$$

$$= \frac{40}{8} = 5\,\text{V}.$$

Magnitude of unmodulated carrier = $\underline{5\,\text{V}}$.

Q11 In a frequency-modulated system a frequency deviation of 70 kHz is observed for a modulating frequency of 10 kHz. Determine

(*a*) *the value of the modulation index,*
(*b*) *the value of the frequency swing.* (3 min)

A11 (*a*)
$$\text{Modulation index} = \frac{\text{frequency deviation}}{\text{frequency of modulating signal}},$$
$$= \frac{70}{10},$$
$$= \underline{7.}$$

(*b*)
$$\text{Frequency swing} = 2 \times \text{frequency deviation},$$
$$= 2 \times 70,$$
$$= \underline{140\,\text{kHz}.}$$

Q12 *Explain briefly the meaning of the following terms as applied to a frequency-modulated wave:*

(*a*) *frequency deviation,*
(*b*) *frequency swing, and*
(*c*) *modulation index.* (*3 min*)

A12 (*a*) The frequency deviation is the difference between the carrier frequency and the maximum instantaneous modulated carrier frequency.

(*b*) The frequency swing is the difference between the maximum and the minimum instantaneous modulated carrier frequencies.

(*c*) The modulation index is the ratio of the deviation to the modulating frequency.

Q13 *State three methods of modulation used to convey digital signals into AC form.*

A13 (*a*) Amplitude modulation,
(*b*) frequency modulation, and
(*c*) phase modulation.

Q14 *The signal voltage at the 75 Ω input terminal of an amplifier is 200 μV. If the signal-to-noise ratio at this point is 1600, calculate the input noise voltage.* (*3 min*)

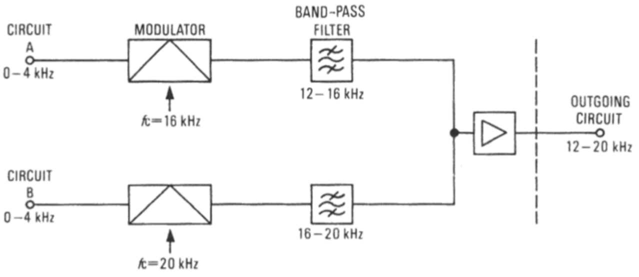
A14
$$\text{Signal-to-noise ratio} = \frac{\text{signal power at input}}{\text{noise power at input}}.$$
$$\therefore \quad 1600 = \frac{(200 \times 10^{-6})^2}{(\text{noise voltage})^2}.$$
$$\therefore \quad (\text{Noise voltage})^2 = \frac{(200 \times 10^{-6})^2}{1600}.$$
$$\therefore \quad \text{Noise voltage} = \frac{200 \times 10^{-6}}{\sqrt{1600}},$$
$$= \frac{200 \times 10^{-6}}{40},$$
$$= \underline{5\,\mu\text{V}.}$$

[*Tutorial Note:* Signal-to-noise ratio is a power ratio; thus with voltage or current values quoted (and a constant resistance),

$$\text{power} = \frac{(\text{voltage})^2}{\text{resistance}} \quad \text{or} \quad (\text{current})^2 \times \text{resistance}.]$$

Q15 *Draw a simple 2-channel frequency-division multiplex system showing 4 kHz speech circuits, A and B, modulated with carriers of 16 kHz and 20 kHz. State the values of the band-pass filters which suppress the upper side bands; also state the nominal outgoing bandwidth.* (*4 min*)

A15



Q16 *From the circuit diagrams in Fig. 1 state which are the high-pass and band-stop filters.* (*2 min*)

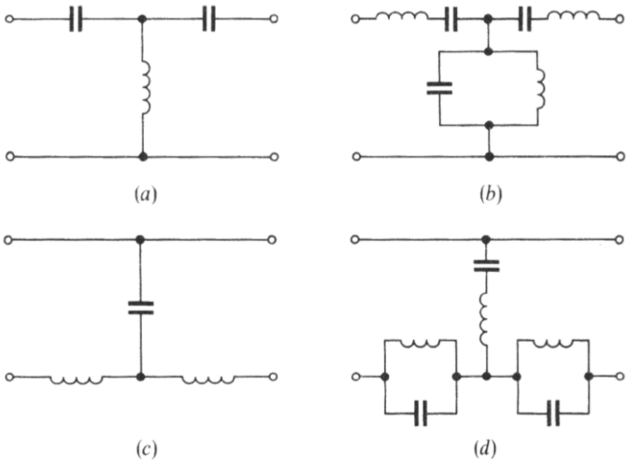


Fig. 1

A16 (*a*) is a high-pass filter; (*c*) is a band-stop filter.

Q17 *The band of frequencies 50 Hz–40 kHz is applied in turn to the filters shown in Fig. 2. For each filter, state the frequencies that appear at the output.* (*3 min*)

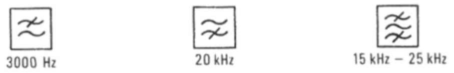


Fig. 2

A17 (*a*) 50 Hz–3000 Hz
(*b*) 20 kHz–40 kHz
(*c*) 15 kHz–25 kHz.

Q18 *Briefly explain the difference between space-, frequency- and time-division multiplexing.* (*5 min*)

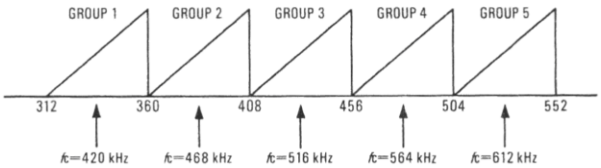
A18 Space-division multiplexing is a technique used for transmitting speech signals over a separate physical path; that is, each circuit on a separate pair of wires in a trunk cable. Frequency-division multiplexing is the transmission of two or more separate speech signals over a common path by using a different frequency band for each signal. Time-division multiplexing gives each speech channel exclusive use of a common transmission path for a series of short intervals of time in rotation with the other channels connected to the system.

Q19 (*a*) *Draw a frequency spectrum diagram for a CCITT supergroup indicating the frequency limits of each group and the carrier frequencies used.*

(*b*) *State:*

(*i*) *the number of supergroups in a basic hypergroup, and*
(*ii*) *the number of speech channels carried on a basic hypergroup.* (*3 min*)

A19 (*a*)



(*b*) (*i*) 16 or 15 supergroups make up a hypergroup, depending on the system.

(*ii*) 960 channels for a 16 supergroup system, 900 for a 15 supergroup system.

Q20 (*a*) *What is the process of sampling a channel on a time-division multiplex system called, and*

(*b*) *how often is a channel sampled if the highest frequency to be transmitted is 4 kHz.* (*2 min*)

A20 (*a*) Pulse-amplitude modulation (PAM).
(*b*) 8000 times per second.

Q21 *Briefly explain the main advantages and disadvantages of time-division multiplex (TDM) systems over frequency-division multiplex (FDM) systems.* *(5 min)*

A21 The main advantages of TDM over FDM are:

(*a*) The noise and distortion which accumulates with distance from the use of amplifiers is extremely difficult to remove from signals transmitted over an FDM system, but is easily removed by regenerators from signals transmitted over a TDM system.

(*b*) The cost of providing an FDM system is higher than an equivalent TDM system.

The main disadvantage of TDM is that it requires a greater bandwidth than an FDM system of similar capacity.

Q22 *In Fig. 3, the power input to the first amplifier is 0 dBm. Calculate:*

(*a*) *the overall loss or gain from input to output; and*
(*b*) *the output power*

(*i*) *in dBm, and*
(*ii*) *in milliwatts.* *(5 min)*

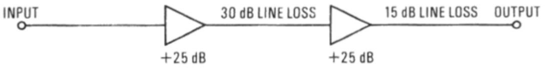


Fig. 3

A22 (*a*) Overall gain = (25 + 25) − (30 + 15) dB

$$= \underline{5\ \text{dB gain}}.$$

(*b*) (*i*) 5 dBm

(*ii*)
$$5\ \text{dBm} = 10\log_{10}\frac{(P_{\text{out}})}{(1\times10^{-3})},$$

where P_{out} is the output power in watts.

$$\therefore\quad \text{antilog}\frac{5}{10} = \frac{P_{\text{out}}}{1\times10^{-3}}.$$

$$\therefore\quad \text{antilog}\,0{\cdot}5 = \frac{P_{\text{out}}}{1\times10^{-3}}.$$

$$\therefore\quad 3{\cdot}162 = \frac{P_{\text{out}}}{1\times10^{-3}}.$$

$$\therefore\quad P_{\text{out}} = \underline{3{\cdot}16\ \text{mW}}.$$

Q23 *Fig. 4 shows a cascaded system with various gains and losses. The output power is required to be −4 dBm. What value of input power is needed to achieve this?* *(5 min)*

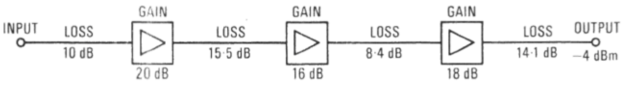


Fig. 4

A24
$$\text{Total gain} = 20\ \text{dB} + 16\ \text{dB} + 18\ \text{dB},$$
$$= 54\ \text{dB}.$$
$$\text{Total attenuation (loss)} = 10\ \text{dB} + 15{\cdot}5\ \text{dB} + 8{\cdot}4\ \text{dB} + 14{\cdot}1\ \text{dB},$$
$$= 48\ \text{dB}.$$
$$\therefore\quad \text{Overall power ratio} = 54\ \text{dB} - 48\ \text{dB},$$
$$= +6\ \text{dB (that is, a gain of 6 dB)}.$$

The required output power is −4 dBm.

$$\therefore\quad \text{Output power} = \text{overall power ratio} + \text{input power}.$$
$$\therefore\quad -4\ \text{dBm} = 6\ \text{dB} + \text{input power}.$$
$$\therefore\quad \text{Input power} = -4\ \text{dBm} - 6\ \text{dB}$$
$$= \underline{-10\ \text{dBm}}.$$

Q24 *With reference to absolute power level*

(*a*) *state the formula used, and*
(*b*) *calculate the absolute power for a signal of 50 mW.* *(3 min)*

A24 (*a*) Absolute power $= 10\log_{10}\dfrac{\text{(actual power in milliwatts)}}{\text{reference power (1 mW)}}\,\text{dBm}.$

(*b*) Absolute power $= 10\log_{10}\dfrac{50}{1}\,\text{dBm},$

$$= 10\times1{\cdot}699\ \text{dBm} = 16{\cdot}99\ \text{dBm},$$

$$\text{or}\quad \underline{+17\ \text{dBm approximately}}.$$

Q25 (*a*) *State the 'maximum power transfer' theorem.*
(*b*) *A source of EMF 3 V and internal resistance 6 Ω is connected to a resistive load. Determine*

(*i*) *the resistance of the load for maximum power to be dissipated, and*
(*ii*) *the value of maximum power.*

A25 (*a*) Maximum power is transferred from a source to a load when the resistance of that load equals the resistance of the source.

(*b*) (*i*) For maximum power transfer $R_{\text{LOAD}} = R_{\text{SOURCE}}$.

$$\therefore\quad R_{\text{LOAD}} = \underline{6\ \Omega}.$$

(*ii*) With $R_{\text{LOAD}} = 6\ \Omega$, the current flowing in the circuit is

$$\frac{3\ \text{V}}{(6+6)\ \Omega} = \frac{3\ \text{V}}{12\ \Omega} = 0{\cdot}25\ \text{A},$$

and the maximum power dissipated in the load is

$$(0{\cdot}25)^2\times6\ \text{W} = \underline{375\ \text{mW}}.$$

Q26 (*a*) *Explain the term 'muldex' as used in higher-order time-division multiplex (TDM) systems.*
(*b*) *Calculate the line bit rate of a 30-channel group.*

A26 (*a*) Muldex refers to the multiplexing and demultiplexing equipment required for both direction of transmission on a higher-order pulse-code modulation system.

(*b*) A 30-channel frame contains 32 × 8 = 256 bit, and so the line bit rate is 256 × 8000 = 2048 kbit/s.

[*Tutorial Note:* 32 time-slots are made up of 30 speech channels plus two synchronisation/signalling time-slots, and 8000 is the sampling rate used for an audio frequency of 3400 Hz on a BT 30-channel pulse-code modulation system.]

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Published by *British Telecommunications Engineering Journal*, 2–12 Gresham Street, London EC2V 7AG,
and printed in Great Britain by Unwin Brothers Limited, The Gresham Press, Old Woking, Surrey